To: Examiner Dave Czejak
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In re Applicant: §
                                        §
        Amir Averbuch   §

Serial No: 10/035,151   §
Filed: January 4, 2002   §   Group Art Unit: 2613
                                        §
For: A METHOD FOR FAST MOTION   §   Attorney   Docket: 01/23082
ESTIMATION USING BI-DIRECTIONAL

AND SYMMETRICAL GRADIENT SCHEMES

Dear Mr. Czejak

With regard to your second and final Office Action, I understood that the if a more exact definition of the center of the parameter interval would have been inserted in the independent claims 1 and 10, this may be have been acceptable as it clearly differentiates my invention from that of Szelinski 6044181. I would appreciate if you could quickly examine amended language inserted herein in claims 1 and 10, which may address the problem of the broad limitation used previously which reads on Szelinski. If necessary further amendments will be necessary to adapt the dependent claims to the new language, I will be happy to provide them.

I plan to call you soon to discuss this matter, and appreciate very much your attention to this case.

Sincerely,

Amir Averbuch

1.   (Original) A method for fast global motion estimation, the global motion defined by a plurality of parameters in which each parameter has an interval, the method comprising:

a. providing a first and a second image,

b. providing an initial estimate of each of two translation parameters, **each said parameter represented by a vector** **in vector space**, and

c. determining the relative global motion between said first and second images using a symmetric gradient approach in an iterative process starting with·said initial estimate of said two translation parameters, whereby said symmetric gradient approach provides the center of each parameter interval and results in improved global motion estimation convergence properties.

2. (Original) The method of claim 1, wherein said step of providing an initial estimate of each of two translation parameters includes

   i. providing an initial interval for each said translation parameter, and

   ii. dividing each said translation parameter initial interval into two equal sub-intervals,

and wherein said step of determining the relative global motion between said first and second images using a symmetric gradient approach includes

   i. providing a basic symmetric gradient formulation that includes said sub-intervals,

   ii. running in each iteration a point-wise linearization procedure on said basic symmetric gradient formulation, and

   iii. deriving in each iteration a symmetric linearization error based on said linearization procedure.

3. (Original) The method of claim 2, wherein said substep of providing a basic symmetric gradient formulation further includes using a motion parameters vector P representing the plurality of parameters.

4.   (Original) The method of claim 3, wherein said step of determining the relative global motion between said first and second images using a symmetric gradient approach further includes: for each iteration:

    i.   calculating separately for each of said first and second images respective first and second $\left(\underline{H}'\,\underline{H}\right)$ matrices,

    ii.   calculating a combined matrix $\left(\underline{H}'\,\underline{H}\right)^{SGM}$ using said first and second matrices,

    iii.   calculating a vector $\underline{H}'\underline{L}$, and

    iv.   calculating a parameters vector $\underline{P}^{SGM}$ using said combined matrix and said vector $\underline{H}'\underline{L}$, and using said symmetric linearization error for a continue/stop check.

5.   (Currently amended) The method of claim 4, wherein said substep of calculating respective first and second $\left(\underline{H}'\,\underline{H}\right)$ matrices includes calculating said matrices using respectively equations [59]

$$\left(\underline{H}'\,\underline{H}\right)^{I_1}_{k,J} = \sum_i \frac{\partial I_1\left(x_i^{(1)}, y_1'\right)}{\partial P_k} \frac{\partial I_1\left(x_i^{(1)}, y_2'\right)}{\partial P_J}$$

and [equation 60]

$$\left(\underline{H}'\,\underline{H}\right)^{I_1}_{k,J} = \sum_i \frac{\partial I_2\left(x_i^{(2)}, y_2'\right)}{\partial P_k} \frac{\partial I_2\left(x_i^{(2)}, y_2'\right)}{\partial P_J}.$$

6.   (Currently amended) The method of claim 4, wherein said combined $\left(\underline{H}'\,\underline{H}\right)$ matrix is calculated according to the following equation [62]

$$\left(\underline{H}'\,\underline{H}\right)^{SGM}_{k,J} = \frac{1}{2}\left(\left(\underline{H}'\,\underline{H}\right)^{I_1}_{k,J} + \left(\underline{H}'\,\underline{H}\right)^{I_1}_{k,J}\right).$$

7.   (Original) The method of claim 1, wherein said global motion is selected from the group consisting from image translation, rotation, affine motion and panoramic motion.

8.   (Original) The method of claim 1, wherein said improved convergence properties include an improved convergence rate.

9.   (Original) The method of claim 1, wherein said improved convergence properties include an improved linearization error rate.

10.   (Original) A method for fast global motion estimation, the global motion defined by a plurality of parameters in which each parameter has an interval, the method comprising:

    a. providing a first and a second image,

    b. providing an initial estimate of each of two translation parameters, **each said parameter represented by a vector in vector space** and

    c. determining the relative global motion between said first and second images using a bi-directional gradient approach in an iterative process starting with said initial estimate of said two translation parameters, whereby said bi-directional gradient approach provides the optimal location of each parameter interval and results in improved global motion estimation convergence properties.

11.   (Original) The method of claim 10, wherein said step of providing an initial estimate of each of two translation parameters includes

    i.   providing an initial interval for each said translation parameter, and

ii.   dividing each said translation parameter initial interval into two non-equal equal sub-intervals,

and wherein said step of determining the relative global motion between said first and second images using a bi-directional gradient approach includes

i.   providing a basic bi-directional gradient formulation that includes said sub-intervals,

ii.   running in each iteration a point-wise linearization procedure on said basic bi-directional gradient formulation, and

iii.   deriving in each iteration a bi-directional linearization error based on said linearization procedure.

12.   (Original) The method of claim 11, wherein said substep of providing a basic bi-directional gradient formulation further includes using a motion parameters vector $\underline{P}$ representing the plurality of parameters.

13.   (Original) The method of claim 12, wherein said step of determining the relative global motion between said first and second images using a bi-directional gradient approach further includes: for each iteration:

i.   calculating separately for each of said first and second images respective first and second $\left(\underline{\underline{H^{t} H}} \right)$ matrices,

ii.   calculating a combined matrix $\underline{\underline{H}}^{BDGM}$ using said first and second matrices,

iii.   calculating a vector $\underline{\underline{H}}^{BDGM} \underline{L}$, and

iv.   calculating a parameters vector $\underline{P}^{BDGM}$ using said combined matrix and said vector $\underline{\underline{H}}^{BDGM} \underline{L}$, and using said symmetric linearization error for a continue/stop check.

14.   (Currently amended) The method of claim 13, wherein said substep of calculating respective first and second $\left(\underline{\underline{H'}}\,\underline{\underline{H}}\right)$ matrices includes calculating said matrices using <u>respectively</u> <u>the</u> <u>following</u> <u>equations</u> [78]

$$\left(\underline{\underline{H'}}\,\underline{\underline{H}}\right)^{I_1}_{k,j} = \sum_i \frac{\partial I_1\left(x_i^{(2)}, y_i^{(2)}\right)}{\partial P_k} \frac{\partial I_2\left(x_i^{(2)}, y_i^{(2)}\right)}{\partial P_j} \qquad \text{and} \qquad \text{equation} \qquad [79]$$

$$\left(\underline{\underline{H'}}\,\underline{\underline{H}}\right)^{I_2}_{k,j} = \sum_i \frac{\partial I_2\left(x_i^{(2)}, y_i^{(2)}\right)}{\partial P_k} \frac{\partial I_2\left(x_i^{(2)}, y_i^{(2)}\right)}{\partial P_j}.$$

15.   (Currently amended) The method of claim 13, wherein said combined $\left(\underline{\underline{H'}}\,\underline{\underline{H}}\right)$ matrix is calculated according to <u>the</u> equation [80] $\underline{\underline{H}}^{BDGM} \stackrel{\wedge}{=} \left[\underline{\underline{H}}^{I_1} \quad \underline{\underline{H}}^{I_2}\right]$.

16.   (Original) The method of claim 10, wherein said global motion is selected from the group consisting from image translation, rotation, affine motion and panoramic motion.

17.   (Original) The method of claim 10, wherein said improved convergence properties include an improved convergence rate.

18.   (Original) The method of claim 10, wherein said improved convergence properties include an improved linearization error rate.